Agro-Science Journal of Tropical Agriculture, Food, Environment and Extension
Volume 7 Number 2 May 2008 pp. 143 -148
ISSN 1119-7455

NITROGEN MINERALIZATION FROM PRUNINGS OF THREE MULTIPURPOSE LEGUME AND MAIZE UPTAKE IN ALLEY CROPPING SYSTEM.

Okonkwo C.I.[1] Mbagwu J.S. C.[2] and Egwu S.O[3]
[1]Department of Soil and Environmental Management
Ebonyi State University. Abakaliki, Nigeria.

[2]Department of Soil Science, University of Nigeria Nsukka, Nigeria.

ABSTRACT

A study was conducted on soil N mineralization in the field in an alley cropping system between 2003 -2005 under two soil depths (0-30cm and 30-60cm) through the utilization of an in-situ soil core technique for studying fluxes of mineral N and its uptake by maize. Result obtained indicated that N mineralization was in the pattern of Gliricidia sepium > Leucarna leucocephala > Cajanus cajan > fertilizer > control. The highest N mineralization of 78.91 mg N Kg-1 soil was obtained in the Gliricidia sepium treatment under 0-30cm soil depth. Between the alley and the fertilizer treatment, cumulative N mineralization was more in the alley treatments. Both mineralization and nitrification processes occurred more in the 0-30cm than 30-60cm soil depths. Among the legumes, low N mineralization, nitrification and ammonification were found in the Cajanus cajan alley treatments. Leaching was more pronounced in the fertilizer than in the alley treatments. However, nutrient uptake was observed highest in the alley treatments showing that nutrient recovery by maize was highest from the mineralization pruning of legumes in alley cropping system.

Key Words: Mineralization, Nitrification, Ammonification, Leaching, Uptake, $N0_3$-N, NH_4-N, Leucaena Leucocephala, Gliricidia sepium, Cajanus cajan, Fertilizer.

INTRODUCTION

Cropping practice involving a close association of trees or shrubs with crops and/or pasture termed agroforestry (Young, 1989), offer potential solution to the problem of declining rural agricultural production in the tropics. Apart from the potential benefits of recycling nutrients from deep soil by trace legume prunnings from woody legumes generally have higher nitrogen content than that of non-legumes because many of them fix nitrogen symbiotically with rhizobia. Crops may benefit from the N supplied when leaves are incorporated as green manure. For this to be successful requires mineralization of N from the prunnings and efficient uptake of the N released by subsequent crops. Although the prunnings from the hedgerows supply enough N for crop growth, the N might be supplied at times or rates that not in synchrony with crop demand. The challenge therefore, is improving N use efficiently in these systems by synchronizing the released nutrient with crop demand.

At International Institute of Tropical Agriculture (IITA) Ibadan, studies in alley cropping system have shown that recovery of this N by maize is low (Kang and Mulongoy 1992, Mulongoy et al 1992). Nitrogen recoveries by maize from pruning as low as 10% alley cropped maize have been reported (Sanginga and Mulongoy 1995).

Leucaena leucocephala has been used in many parts of the world as green manure for maize and rice (Pound and Martinez-Cairo, 1993). Because of its high nitrogen fixation potential, which may reach 350kg N ha^{-1} (Sanginga et al, 1988), Leucarna leucocephala has been the most studied woody legume. However, for low pH soils such as in Abakaliki, Gliricidia sepium and *Cajanus cajan* which abound in the area, were brought into the alley cropping system.

This study outlines the mineralization process in alley cropping system of three woody legumes- *Leucaena leucocephala, Gliricidia sepium and Cajanus cajan.* Two types of studies were conducted, one no N mineralization from incorporated prunnings in the field through the monitoring of ammonification (NH_4^+ - N) and nitrification ($N0_3^-$ - N) processes and the sound, on the leaching and uptake of N by maize crops.

MATERIALS AND METHODS

Location

The experiment was conducted for three years (2003 – 2005) in an existing alley cropping system of three multipurpose legumes – *Leucaena leucocephala, Gliricidia sepium and Cajanus cajan* (Pigeon Pea), in the experimental site of the Faculty of Agriculture and Natural Resources Management, Ebonyi State University, Abakaliki, in the South Eastern Nigeria.

Experimental Design

The experiment was established using a randomized complete block design (RCBD) with four replications and five treatments. The treatments were:

10t ha^{-1} of Leucaena leucocephala prunnings,
10t ha^{-1} of Gliricidia sepium prunnings,
10t ha^{-1} of Cajanus cajan prunnings,
300kg ha^{-1} NPK 20-10-10fertilizer,
Control plots with no prunnings and no fertilizer.

Field incubation

The fresh prunnings were incorporated to a depth of 0-30cm in the their respective alleys. Beds measuring 15m x 4m were prepared within the plots. An in-situ methodology for studying mineralization (fluxes of mineral) –N) of soil N (and its uptake by plants) described by Raison et al (1987) was used. Three pairs of polyvinyl chloride (PVC) tubes measuring 5cm in diameter and 65cm in length were inserted into the soil to a depth of 60cm as follows: after the incorporation of fresh prunnings, after fertilizer application and in the control plots at the same time The PVC tubes were placed randomly in groups of three (A, B and C) in each plot. Tube A was removed immediately and returned to the laboratory. The unrecompensed materials were carefully removed and soil from the core divided into 0-30cm and 30-60cm and analyzed for the time zero for NH_4 H and $N0_3$ N. The remaining tubes were incubated in the field for 3 weeks. Tubes B were covered with plastic cup to keep out moisture and avoid leaching loses, while tubes C were open. After 3 weeks, tubes B and C were removed to assess the accumulated mineral N, and another tubes D were inserted and removed immediately for analysis. The difference between the mineral N accumulated in tubes D and tube C were assumed to be the estimates of plant N uptake. In the laboratory, the cores were pushed out of the tubes and divided into two sections, 0-30cm and 30-60cm. Soil samples were extracted with 0.5m K_2SO_4. This was shaken for 30 minutes, followed by filtration, and the filtrate was analyzed for NO_3-N using technique described by Gine et al (1989) and NG4-N analysed using procedure described by Alves et al; (1992). The following expression as described by Scholes and Sanchez (1991) was adopted. $N0_3^-$ = extractable nitrate NH_4^+ = extractable ammonium, a = Time zero, bulk soil b = Time one, covered soil c = Time one, uncovered soil d = Time one bulk soil.

1. Net ammeralization = $(NH_4^b + N_3^b) - (NH_4^a + N0_3^a)$
2. Net ammonification = $NH_4^b - NH_4^a$
3. Net nitrification = $N0_3^b - N0_3^a$
4. Leaching = $(NH_4^b + N0_3^B) - (NH_4^C + N0_3^C)$
5. Uptake = $(NH_4^d + N0_2^d) -$ (Leaching)

Plant Establishment

Maize variety Oba super II was planted one week after incorporation (WAL) of prunnings at a plating distance of 25cm intra-row spacing and 75 cm inter-row spacing giving a 50,000 stands per ha. Two grains were planted per hill and thinned down to one per stand at 14 days after planting. NPK (20-10-10) fertilizer was applied immediately after thinning at the rate of 3000kg ha^{-1}. There were repeated pruning of the alley hedgerow to prevent shading. Pruned material was removed from the plots to avoid compounding mineralization process. At WAI five tagged maize plants per plot were assessed for nutrient content of maize ear leaf using Reuter and Robinson (1986) methods. All the data obtained in this study were analyzed statistically, using SAS (1985).

RESULTS AND DISCUSSION

Mineralization

The cumulative N mineralization in the control plots, alley plots (receiving prunning) and the fertilizer plots are presented in Table 1. The pattern of N mineralization was in the following order: *Gliricidia sepium*> *Leucaena leucocephala*> *Cajanus cajan*> fertilizer> control. Mineralization was highest in Gliricida. Sepium plots in all the years of study (41,90 N kg^{-1} soil in 2003, 55.0 N kg^{-1} soil in 2004 and 78.91 N kg^{-1} soil in 2005) at 0-30cm depth. These showed significant increases ($p<0.05$) in N mineralization over the other legume species, fertilizer and control plots. Mineralization was lowest at all periods of study at 30-60cm and the lowest obtained in 2003 in the *Cajanus cajan* alley plots (22.50 N kg^{-1} soil). Between the alley plots and the fertilizer plots, cumulative N mineralization was more in the alley plots, in the three years of study. The lowest N mineralization occurred in the control plots at all depths (11.28 N kg^{-1} soil in 2003, 17.97 N kg^{-1} soil in 2004, and 20.40 N kg^{-1} soil in 2005).

There were consistent differences in mineralization over time at the two study depths in plots treated with either prunnings or fertilizer and the control plots. More N mineralization ccurred at the 0.30cm depth than at the 30-60cm depth. However, palm and Sanchez (1991), in their studies of N mineralization with *Sesbania sesban* leaves at two different depths (0-20cm and 20-40cm), observed slight differences at the study depths. The result of this study, did not fully agree with that of Palm and Sanchez (1991) since results showed decreases in N mineralization at lower soil depths (30-60).

Nitrification and Ammonification

Data on nitrification and ammonification as shoen in Table 1, indicated that greater activities on these two processes were more in the top 0-30cm depth, than the 30-60cm and with increasing time of study. The highest $N0_3$-N of 59.60 N kg^{-1} soil was obtained in the Gliricidia sepium, alley plots in 2005. In the same year, fertilizer introduced $N0_3$-N to the level of 28.30 mg N kg^{-1} soil at the same depth, while the control plots had 6.63 mg N kg^{-1} soil. Both *Leucaena leucocephala* and Cajanus cajan with values 32.0 mg N kg^{-1} soil and 29.35 mg N kg^{-1} soil, respectively were significantly higher than the values obtained in the fertilizer and control plots at 30-60cm depth. The values obtained for ammonification in similar depths increased in all the years but were not as high as values obtained for nitrification. In 2005, NH_4-N values were 28.07 mg N kg^{-1} soil in Gliricidia sepium plots, 25.20 mg N kg^{-1} in *leucaena leucocephala* plots and 21.33 mg N kg^{-1} soil in the Cajanus cajan plots. The NH_4-N in both the fertilized and control plots were 12.07 mg N kg^{-1} soil and 8.37 N kg^{-1} soil respectively. The nitrification and ammonification processes have shown that increased $N0_3$-N to NH_4-N may have resulted from better aeroic condition in the 0-30cm soil depth than I the 30-60cm depth. The $N0_3$-N levels were high in the high N input system and very low in both the fertilized and control plots. Thus, hedgerow prunnings from the legume trees in alley plots with high N value (Table 1) supported better yield of $N0_3$-N. the low level of NH_4 N in this work could be that as soon as they were formed they were rapidly converted to $N0_3$ –N by nitrification. Among the legumes prunning, the low N mineralization, nitrification and ammonification were found in the Cajanus cajan alley plots as compared to the Gliriicidia sepium or Leucaena. Leucocephala alley plots. This was related to the low N content of the Cajanus cajan prunnings. Comparing the fertilized and control plots with plots receiving prunnings (from the legume hedgerow tree in alley), it was observed that the three processes were low in the former two treatments (fertilizer and control).

Leaching and Uptake

Values obtained for maximum leaching and uptake are presented in Table 2. Leaching was more in the fertilized plots at the various depths. Mineralized N was leached more at the depth of 0-30cm with a total of 60.30 mg Nkg $-^{1}$ soil in the fertilized plots. Leaching was considerably low in all the alley plots compared with the fertilized plots. The lower leaching values were obtained from the control plots throughout the study. The least occurred in 2005 (1.73 Nkg^{-1} soil) at the same depth (0-30cm). However, not much of the leaching process was observed at 30-60cm depth. The highest leaching values at this depth were obtained in the fertilized plots (10.50, 21.62 and 12.98 Nkg^{-1} soil) in the three-year study periods respectively.

A large proportion of the mineral N found in the 0-30cm soil depth constitute N uptake for maize plant. The highest N available for maize uptake was observed in the year 2005 at both study depths (0-30cm and 30-60cm). The total available N of 61.82 N kg^{-1} soil, 101. 60 N Kg^{-1} soil and 106.40 N kg^{-1} soil were obtained from the Gliricidia sepium alley plots. These values were significantly different ($p<0.05$) from all the other treatments both *Leucaena leucocephala* and *Cajanus cajan* alley plots had higher N values for maize uptake, than the fertilized and control plots and showed significant differences ($p<0.05$) over them. The lowest N available for maize uptake occurred in the control plots throughout the period of study. The high level of mineral N at 0-30cm was advantageous for the early growth of maize. However, because of the rooting pattern of maize, mineral N within 40cm depth will still be absorbed by the maize plants. When the total mineral N available for maize uptake, resulting from the prunnings of *Gliricidia sepium, Leucaena leucocephala* and *Cajanus cajan* are compared to the fertilizer N, it became obvious that more N came from the prunings than from fertilizer in the study. A greater percentage of mineral N from fertilizer were found in the leaching process. Thus, the N from fertilizer might have been completely released at the peak of the leaching process. Therefore, the decomposition rate of the punned materials controlled N release and more N from pruned materials were utilized by maize than that of fertilizer N, which might have been released very fast and leached beyond the rooting zone of the maize plant.

Nutrient Content of Ear leaf

At 7WAI ear leaf samples showed that the incorporated pruned materials in the alley plots supplied better nutrient than fertilizer (Table 3). The most important nutrient was N. Among the different alley plots, the least amount of N in the ear leaf was from the C. cajan plots, with a total N content of 173kg N ha^{-1} in 2005, while both L. *leucocephala* and *G. sepium* had 210kg N ha^{-1} and 256kg N ha^{-1} respectively in the same year of study. The N content of ear leaf of maize grown in the fertilized plot was 80kg N ha^{-1}.

Between 2003 and 2005, the N content of maize ear leaf was higher in the G. sepium alley plots. *Gliricidia sepium* within these periods showed significant increase ($p<0.05$) over Cajanus cajan and Leucaena. Leucocepehala. The N content on the maize ear leaf as observed in this study, far exceeded that obtained by Mulongoy and Gasser, 1993, and Kang and Mulongoy, 1992, who reported that the effective N from *Leucaena* and *Gliricidia* alley cropped maize was estimated to be less than 90 kg N ha^{-1}. The higher N content in the maize ear leaf of 256kg N ha^{-1} and 210kg N ha^{-1} in G. sepium and *Leucaena leucocephala* alley plots as observed in this study, suggested that he main contribution of the legume prunnings to maize was N. The N found in the ear leaf of maize from each of the pruning materials in alley cropping treatments far exceeded that supplied by inorganic fertilizer.

Besides N prunnings also supplied substantial amount of P, K, Ca and Mg. The highest P in the ear leaf occurred in the *Cajanus cajan* alley plots (254 mg Kg^{-1}) in 2005. This was significantly different ($p<0.05$) from all the other treatments. Both Ca and Mg increased appreciably in the maize ear leaf of *Leucaena leucocephala* and *Gliricidia sepium* alley plots and were significantly different ($p<0.05$) from the other treatments.

However, the fertilizer plots showed significant difference ($p<0.05$) from *Cajanus cajan* in the amount of Mg content in the maize ear leaf. The levels of P, K, Ca and Mg in the maize ear leaf from the control plots were very low compared with the other treatments and decreased from year to year. The high nutrient recorded in the maize ear leaf from the alley plots indicated that the pruned materials from the three legumes hedgerow trees have enough nutrients for crop growth.

Table: 1 Net N- Mineralization, Nitrification and Ammonification As Affected By the Incorporated Pruning and Fertilizers In An Alley Farm. (mg N kg^{-1} Soil)

							2003								
	N-MINERALIZATION					NITRIFICATION					AMMONIFICATION				
Treatments	Time 0-30 cm		Time 30-60cm		Total	Time 0-30 cm		Time 30-60 cm		Total	Time 0-30 Cm		Time 0-30 cm		Total
	Zero	3WAI	Zero	3WAI		Zero	3WAI	Zero	3WAI		Zero	3WAI	Zero	3WAI	
Leuceana	3.98	36.53	1.42	27.49	64.02	2.92	33.89	1.78	20.94	54.83	1.34	16.94	0.84	12.59	29.53
Gliricidia	4.01	41.90	1.85	29.77	71.67	3.24	38.68	1.92	21.40	60.08	1.41	18.71	0.91	13.38	32.09
Cajanus	3.87	34.00	1.09	22.53	56.53	2.88	28.63	1.66	18.54	47.17	1.31	15.34	0.80	10.28	25.62
300kg ha^{-1} NPK	3.92	21.29	0.87	13.44	34.73	2.78	17.49	1.58	14.46	31.95	1.30	4.89	0.84	2.98	7.87
Control	1.05	11.28	0.35	9.20	20.48	1.69	3.72	1.04	1.67	5.39	1.29	1.56	0.60	0.83	2.39
LSD (0.05)	NS	4.81	NS	3.54	7.09	NS	4.02	NS	2.33	6.71	NS	1.64	NS	1.58	3.96
							2004								
Leuceana	6.82	48.24	3.34	30.66	78.90	9.34	42.31	6.83	28.44	70.75	3.38	21.00	1.38	16.32	37.32
Gliricidia	9.60	55.01	6.46	32.91	87.92	12.46	49.76	9.40	30.12	78.88	4.11	25.65	2.17	16.01	41.66
Cajanus	5.34	40.33	3.08	26.84	67.17	8.68	36.55	5.98	21.31	57.88	2.96	17.24	1.26	14.46	31.70
300kg ha^{-1} ^{1}NPK	4.28	28.42	3.10	18.53	46.93	5.10	20.01	3.96	14.28	34.29	1.98	8.04	0.98	3.12	11.16
Control	2.35	17.97	2.06	1.43	19.22	4.92	12.22	3.86	8.84	21.04	1.65	5.71	0.75	1.66	7.37
LSD (0.05)	2.06	5.31	1.58	2.12	10.56	1.56	4.87	1.54	2.92	8.84	0.84	2.36	0.31	1.87	3.02
							2005								
Leuceana	15.22	62.78	11.44	42.30	105.08	12.00	54.38	8.12	32.00	86.38	5.32	25.21	1.51	19.40	44.61
Gliricidia	19.34	78.92	13.96	50.22	129.14	16.28	59.62	10.36	35.07	94.69	7.08	28.07	2.98	21.32	49.39
Cajanus	13.28	59.44	10.74	31.60	91.04	10.36	46.04	7.98	29.35	75.39	4.10	21.33	1.74	16.58	37.91
300kg ha^{-1} $^{-1}$NPK	8.41	32.36	5.86	20.32	52.68	6.04	28.30	4.01	17.01	45.31	2.36	12.07	1.32	9.36	21.43
Control	4.69	20.40	3.64	14.08	34.48	5.32	16.44	3.16	6.63	23.07	2.03	8.37	1.03	2.04	10.41
LSD (0.05)	2.35	10.38	2.04	5.02	15.46	2.14	5.46	1.84	3.91	10.38	1.67	3.21	0.53	3.02	4.27

Table 2: Leaching and Uptake of N measured at 3 WAI as affected by pruning and fertilizer in alley cropping system.

	LEACHING			UPTAKE		
	0.3cm	30-60cm	Total	0-30cm	30-60cm	Total
Treatments				N kg^{-1} Soil.		
			2003			
Leucaena	9.32	5.04	14.36	36.70	20.28	56.98
Gliricida	8.74	4.91	13.65	43.06	18.76	61.82
Cajanus	6.08	3.87	9.95	31.29	19.89	51.18
300kg ha^{-1} NPK	25.22	10.56	35.78	10.61	32.67	33.28
Control	2.16	1.10	3.26	4.15	2.23	6.38
LSD (0.05)	2.14	1.94	3.97	3.69	2.91	7.64
			2004.			
Leucaena	19.24	13.84	33.08	55.06	36.37	91.43
Gliricida	17.30	10.33	27.63	68.74	32.86	101.60
Cajanus	12.08	7.05	19.13	50.32	20.04	70.36
300 Kg ha^{-1} NPK	52.36	21.62	73.98	20.46	43.28	60.74
Control	3.10	2.09	5.19	6.68	3.96	10.64
LSD (0.05)	3.84	2.61	7.17	6.32	4.08	12.86
			2005			
Leucaena	12.17	8.41	20.58	60.32	39.22	99.54
Gliricida	11.50	7.01	18.51	76.00	30.04	106.40
Cajanus	10.91	4.19	15.10	54.46	26.32	80.78
300Kg ha^{-1} NPK	30.27	12.98	43.25	20.38	46.00	66.38
Control	1.73	0.90	2.63	10.77	2.44	13.21
LSD (0.05)	1.13	1.07	3.33	8.91	4.06	15.02

Table: 3 Nutrient Composition of maize ear leaf under alley cropping system.

Treatments	Org C	N	P	K	Ca	Mg
	%			Kg ha^{-1}		
			2003			
Leucaena	1.54	125	84	28	48	20
Gliricidia	1.31	160	102	21	67	27
Cajanus	1.91	110	156	17	50	21
300 kg ha^{-1} NPK	1.42	98	92	19	66	33
Control	0.68	30	55	12	21	14
LSD (0.05)	0.42	32	17	1.8	5.21	2.34
			2004			
Leucaena	1.74	180	110	33	67	43
Gliricidia	1.58	204	124	40	82	38
Cajanus	2.25	156	198	23	72	32
300 kg ha^{-1} NPK	1.86	90	104	22	80	47
Control	0.32	28	67	14	39	16
LSD (0.05)	1.04	48	36	3.31	5.63	3.33
			2005			
Leucaena	2.02	210	138	41	88	51
Gliricidia	1.90	256	166	56	97	69
Cajanus	2.46	173	254	30	80	44
300 kg ha^{-1} NPK	2.17	80	112	26	72	50
Control	0.21	22	84	18	52	20
LSD (0.05)	1.22	57	54	4.24	1.80	4.04

CONCLUSION

Mineralization of prunnings from alley cropping hedgerow trees maintained higher soil nitrogen and nutrient levels than both the fertilized and control treatments. The highest mineralized N was obtained from the *G. sepium* prunnings and this yielded the highest N content in the ear leaf of maize. Both mineralization and nitrification were pronounced in the 0-30cm soil depth, with more accumulation of $N0_3$-N than NH_4-N in this soil depth. Leaching was highest in the fertilizer treatment than in any other treatment in this experiment. Nutrient availability and utilization were highest in the alley plots where N mineralization of prunning occurred. In all, the high nutrients recovered by maize from the mineralized prunnings in the alley treatments, indicated that the pruned materials from the three legumes hedgerow trees had the potential of improving soil nutrient quality and sustain crop production.

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